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SOLID WASTE LANDFILL SITE SELECTION FOR GREATER VISAKHAPATNAM MUNICIPAL CORPORATION USING REMOTE SENSING AND GIS

VICTOR BABU NEELA

Associate Professor, Department of Civil Engineering, BABA Institute of Technology and Sciences, Visakhapatnam, Andhra Pradesh, India

ABSTRACT

Municipal solid waste generation is among the most significant sources which threaten the global environmental health. Site selection is an important and necessary issue for waste management in fast-growing countries like India. Because of the complexity of waste management systems, the selection of the appropriate solid waste landfill site requires consideration of multiple alternative solutions. Remote sensing data have been used to present conditions of the land use/land cover and geomorphology of the study area. All factors affecting the site environment were considered as per the guidelines of waste management and handling rules (2008) that include physical environment, man made network facilities. A Geographic Information System (GIS) was used for selection of landfill sites. Suitability maps were graded from 0 (lowest suitability) to 10 (highest suitability) using spatial information technologies. Suitable landfill areas represent optimal sites. The selected sites are Kottatalarivanipalem (1.81 km^2), Denduru (1.56 km^2), Yeduruvanipalem (1.07 km^2), Pydivada Agraham (1.03 km^2), Mantripalem (0.97 km^2), Mindivanipalem (0.91km^2) and Ramayogi Agraharam (0.89 km^2). The landfill site which covers large area may last longer period. My work can offer a sitting methodology and provides essential support for decision-makers in the assessment of waste management problems in the area and other rapidly developing cities in India. The results shows the Greater Visakhapatnam Municipal Corporation (GVMC) dumping site should follow the guidelines and recommendations given by the researcher for further managing and eradicate environmental issues in the environ of GVMC.

KEYWORDS: Solid Waste, Landfills, GIS and Remote Sensing

INTRODUCTION

The study area is famous for industries, owing to industrialization, the neighboring rural people are migrating for employment and it could be one of the reasons for population boom and urban slums. Municipal Solid Waste (MSW) management is an important aspect for environmental conservation especially in the densely populated industrial and urban areas (Bhoyar *et al*., 1996). The Greater Visakhapatnam Municipal Corporation (GVMC) is currently handling urban solid waste in an improper manner resulting in spread of diseases, fire hazards, atmospheric, surface and groundwater pollution. Proper management of solid waste plays an important role in health and well-being of urban residents (World Bank, 2003). In this study, municipal solid waste is estimated at 0.525 kg/head/day. Due to negligence in dumping of municipal solid waste by residents, it is leading to unhygienic conditions and this scenario is very severe in the vicinity of major drainages (gedda). Almost all major unlined sewage drainages act as conduit to transmit pollutants into the groundwater (Jagadeeswara Rao, 2004). The accumulation and improper disposal of solid waste leads to environmental pollution and accelerates the spread of communicable diseases (George Tchobanoglous, 1993). The present study is focused on identification of landfill sites using geospatial technologies for Municipal Solid Waste management (MSWM).

STUDY AREA

The study area is delinated on the basis of drainage divide occupy 1143 km^2 lies in between 17^o 31’ 42’’ - 17^o 55’ 29’’ Northern Lat and 83^o 2’ 5’’ - 83^o 25’ 17’’ Eastern Long. Visakhapatnam District, Andhra Pradesh (Figure 1). The Greater Visakhapatnam Municipal Corporation (GVMC) covers an area of 545 km^2 lies in the study area, Physiographically, the Kailasagiri and Yaradakonda hills altitude varies from 507 to 357 m above msl. The study area appears as saucer shape and is bordered by the Bay of Bengal on eastern side.

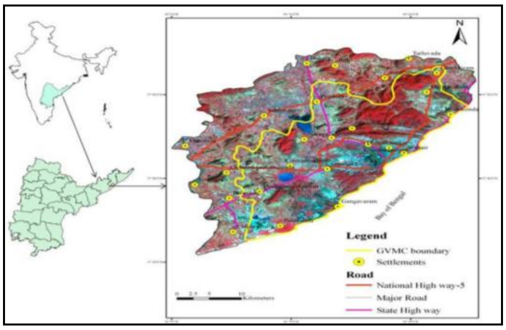

Figure 1: Location Map of the Study Area

The study area falls in Eastern Ghats Mobile Belt (EGMB) composed of high-grade metamorphic rocks and igneous intrusive bodies. Drainage pattern has been severely altered by anthropogenic activities. Major rivulets become unlined sewage drains which are the major source for surface and groundwater pollution. The average annual rainfall of the area is around 1201mm. In the study area, Kambalakonda, Narava, Nadupuru reserved forests occupy an area of 33.33 km^2. The 72 municipal wards in GVMC are grouped into VI zones.

METHODOLOGY

In this study, thematic maps of base map, drainage map, geomorphology, land use/land cover and lineaments have been generated using Survey of India toposheets of 1:50,000 scale and IRS-1C and P6-LISS-III in the preparation. The study area toposheets and satellite imagery are geometrically rectified in ERDAS Imagine 9.1 environment. The soil and geology maps are extracted from the District Soil and District Geology and Mineral map. Thematic maps were digitised and assigned non-spatial data for analysis in ArcGIS-9.2. The criterias for lineaments, roads and 3^{rd}, 4^{th} order drainages were assigned following the standard guidelines of Municipal Solid Waste (Management and Handling) Rules 2000 for the selection of landfills. The drainage, soil, geology, geomorphology, road, lineament and major settlements for obtaining landfill sites. GIS is a tool that not only reduces time and good spatial site selection but also provides a digital data bank for future monitoring of the site (Miles *et al*., 1999). The output obtained from the intersection of drainage, roads and settlements are intersected with soil, geology, geomorphology and lineaments. The output was converted into a raster layer using vector to raster in ArcGIS-9.2. The raster layer and ASTER-30 DEM were analysed for identification of landfill sites using weighted overlay techniques. In this process sixteen landfill sites were selected. The sites fallen in GVMC area are excluded and remaining sites covering more than 1km^2area is finally selected (Figure 2).

RESULTS

The spatial arrangement of drainage pattern reveals surface and subsurface characteristics being of an area controlled by soil, rock type, rock structure, meteorological conditions and anthropogenic activities. Drainage orders were assigned following the Strahler (1952) stream ordering. Rill and gullied erosion observed at foot hill areas which are highly erodable due to slopes, rock types, sparse vegetation composition and type of soil, etc. Different types of drainages, such as

radial, dendritic to sub-dendritic are prominently seen at places. Canals were updated from the satellite imagery. Highest 6th order drainage has been identified in the drainage areas of Marikavalasa gedda and Meghadri gedda. Drainage has been severely altered by anthropogenic activities.

Groundwater is a major source for domestic use is categorized into three zones, viz. weathered zone, back water zone and industrial zone (Subba Rao and Krishna Rao, 1990). About 25 dug wells adjacent to unlined major streams (gedda) have been inventoried during pre and post-monsoon, in 2011 revealing shallow (1m) to deep (15m) water table configuration. The soil map of the study area is digitized from the Visakhapatnam district soil map. In this, nine soil types are observed in which 87% area is under red clay soil. Scientists have emphasized the importance of aerial photographs and satellite imagery in structural analysis, especially in lineament mapping (Prudhvi Raju and Vaidyanadhan, 1981). The confirmed lineaments are the major geological structures (faults) mostly occupied by the rivers/rivulets where landmass denudation is taking place. The trends of the confirmed lineaments are observed in NW-SE directions.

Geomorphology maps can be utilized for regional land use planning and restoration of the eco-balance (Chopra, 1990). The fluvial and erosional landforms of the area have been delineated following the standard visual interpretation techniques on IRS-IC-LISS-III satellite image (RGNDWM, 1996) in which pediplain shallow-weathered is the major class followed by pediplain moderate-weathered. The Geology of the study area is Khondalite suite of rock belongs to Pre-Cambrian, its structural trend is N-NE-S-SW and it is similar to the general trend of the Eastern Ghats with a few local variations (Sriramadas, 1952, Chetty *et al*., 2002). About 90% of the area is occupied by khondalite rock, charnockite and quartzite occurring as ridges.

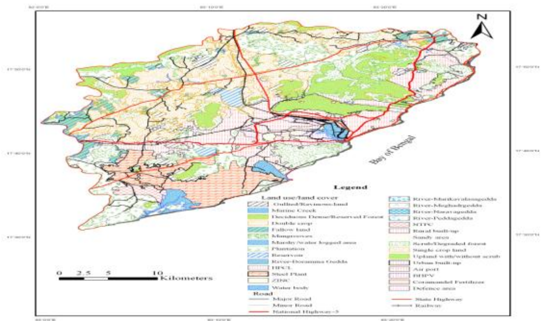

Figure 3: Land Use/Land Cover Map

In this analysis, IRS-1C, LISS–III, October, 2004 and IRS-P6-LISS-III, January, 2011 digital satellite data have been used. In this, 30 land use/land cover classes were delineated following the NRSC guidelines (1990), in which urban built-up covers 296.06 km^2 (Figure 3). It is observed that the urban area is progressing towards north-east side, whereas, industrial zone is progressing towards south- east. Minor land use features have not been identified on the satellite images due to resolution constraint. Also observed that waste/fallow lands are being converted into urban built-up and mangroves are also disappearing due to industrial/urban built-up. The study area appears as bowl shape rimmed by structural hills. Major hill ranges are covered with hydrophilic soils supporting luxuriant dry deciduous forest occupies 143.77km^2 (2011). Isolated hillocks are being quarried for building materials. Hills in Bheemunipatnam area are covered by IT parks; Cinema studies, etc. are responsible for deforestation. Most of the urban slums near Kancharapalem, Tadichatlapalem and Arilova are encroached foot hill areas. Major roads are delineated and street roads are not delineated due to resolution constraint and updated recent road network on the basis of satellite image. Intensive agriculture is observed in the upstream areas of Meghadrigedda Reservoir. Paddy is the major food crop besides vegetables, ragi, maize and bajra, etc. in the villages of Vemulavalasa, Pinagadi, Chintala Agraharam and Sabbavaram.

WEIGHTS

Weights have been assigned to each class of all thematic maps for GIS analysis. Weights range between 0 to 10 in which 0 stands unsuitable, whereas, 10 stands suitable. There are more than 9classes in the thematic layers of Geomorphology and land use/land covers are considered most suitable classes (Table 1).

Table 1: Features in Each Theme and Weight Factors

Theme	Identified Feature	Source	Weight	Landfill Site Suitability
Geomorphology	Denudational hill Inselberg Intermountain valley Valley fill-shallow Pediplane shallow-weathered Pediplane moderate- weathered Pediplane deep- weathered Piedmont slope	Remote sensing	02 03 06 07 10 09 05 08	Unsuitable Unsuitable Unsuitable Unsuitable Suitable Suitable Unsuitable Unsuitable
Lineaments	Confirmed Inferred	Remote sensing/SOI Toposheets	00 09	Unsuitable Suitable
Slope	0-1% 1-5% 5-10%	SOI Toposheets	10 09 08	Suitable Suitable Unsuitable
Drainage	Third order streams Fourth order streams	SOI Toposheets	Buffer in mts 500	Sites away from the buffer zones were selected
Water bodies	Reservoirs Rivers	Remote sensing	Buffer in mts 500 500	Sites away from the buffer zones were selected
Roads	NH-5 Major roads	SOI Toposheets	Buffer in mts 2-3 Km 0.5-2 Km	Suitable
Land use / land cover	Single crop land Fallow land Plantation Built-up Upland with/without scrub Gullied/ravenous land	Remote sensing	09 10 04 01 07 05	Suitable Suitable Unsuitable Unsuitable Unsuitable Suitable
Geology	Khondalite Charnockite	GSI map	10 04	Suitable Suitable
Soil	Red clayey soil Clayey soil Red loamy soil	District Soil map	10 09 08	Suitable Suitable Suitable

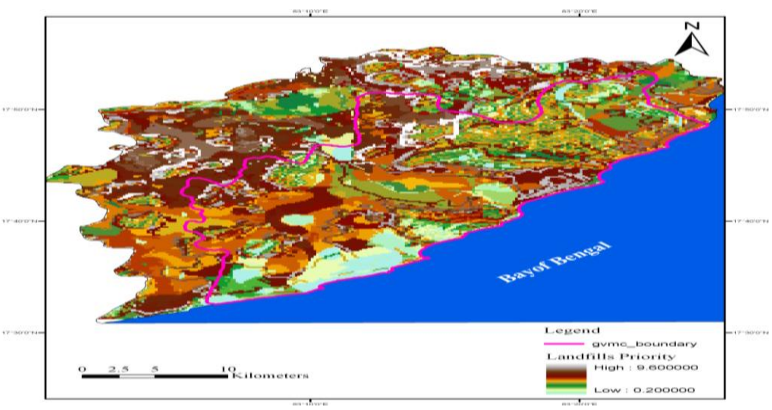

Figure 2: Weighted Overlay Map

GIS ANALYSIS

Following the local body and Waste Management and Handling rules (2000), landfill sites must not be near to rivers, lakes and ponds. About 1000m buffer was assigned to major settlements, similarly, to avoid surface water contamination, 500m buffer was assigned to 3rd and 4th order drainages, water bodies and roads. Minor stream order areas are not been considered in the landfill site selection, because these areas has steep slopes. The areas with high slopes are not suitable for waste disposal; similarly, moderate slope areas are also not suitable (Jagadeeswara Rao *et al*., 2007). The 0-5% slope is covered with plains and gentle slope areas which include land use/land cover classes of fallow lands, waste lands and agriculture lands in the plain areas, and geomorphologically, covered pediplain shallow-weathered, pediplain moderately-weathered and intermountain-valleys. The soils covered in this category are red soils. For landfill site selection, plains are suitable areas which are under 0-1% and 2-5 % slope category covered 673 km^2 and 183.80 km^2 considered on the basis of surface run-off and land mass denudation, etc. Considering solid waste management rules, weights were assigned on the basis of terrain characteristics of each class. Owing to steep slopes, the denudation hills, structural hills and pediment inselberg complexes are excluded whereas, pediplain-shallow weathered and pediplain-moderately weathered are considered for site selection analysis. In this analysis, state high-ways and district roads are considered. The waste disposal sites should not be located in densely populated urban or rural areas. The depth of water table is a significant parameter in determining the contamination risk of groundwater. The topography and soil type affects the rate of infiltration into the water table. Different weights are assigned to geological rock types, geomorphological classes, soil types and land use/land cover. In this sixteen landfill sites are selected. The sites selected in GVMC area is not considered because these falls in urban built-up. Finally seven sites are selected other than the sites in GVMC area for solid waste management (Figure 4). The selected landfill sites are ranked as Kottatalarivanipalem (1.81 km^2), Denduru (1.56 km^2), Yeduruvanipalem (1.07 km^2), Pydivada Agraham (1.03 km^2), Mantripalem (0.97 km^2), Mindivanipalem (0.91km^2) and Ramayogi Agraharam (0.89 km^2) (Table 2). The landfill site which covers large area may last longer period than the small area.

Table 2: Suitable Landfill Sites Identified in the Analysis

S. No	Name of the Village	Distance of the Road in km.	Area Km^2	Latitude	Longitude
1.	Kotta Talarivanipalem	1.58	1.81	17˚.42’38.984”N	83˚.03’51.169”E
2.	Pydivada Agraharam	0.71	1.03	17˚.44’41.14”N	83˚.06’51.865”E
3.	Mindivanipalem	0.98	0.91	17˚.52’14.082”N	83˚.18’38.734”E
4.	Ramayogi Agraharam	0.72	0.89	17˚.52’27.399”N	83˚.24’36.503”E
5.	Yeduruvanipalem	0.58	1.07	17˚.39’25.344”N	83˚.04’16.494”E
6.	Denduru	1.14	1.56	17˚.51’55.395”N	83˚.09’20.808”E
7	Mantripalem	1.45	0.97	17˚.41’45.253”N	83˚.5’26.941”E

DISCUSSIONS

The study area is one of fast developing cities in India. The study area consists of GVMC, major industries, agriculture, etc. As per 2011, the solid waste dumping is around 1075 T/day at 9 year old Kapula Uppada dump yard. The site is almost filled with solid waste, it may not accommodate further. Similarly, the site comes under the jurisdiction of GVMC. As per management and handling rules, 2000, the landfill sites should be away from urban built-up. Several constructions have come up near this site in recent years which is a violation. The present site was used by VMC (100 km^2), but its jurisdiction has been extended to 545 km2 and also the population doubled in last two decades. Solid waste in the area should be properly managed in order to keep the surrounding clean and neat.

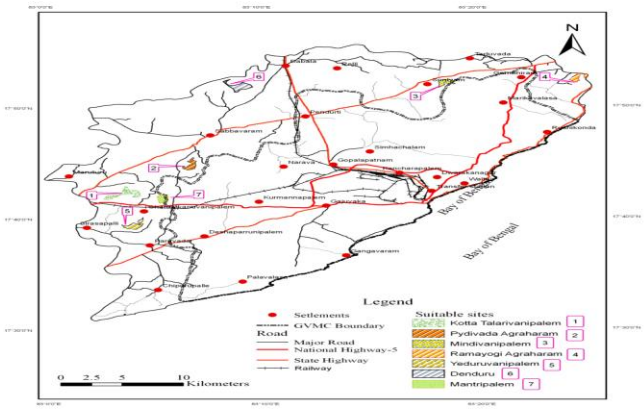

Figure 4: Selected Landfill Sites in the Study Area

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